BISTATE HID OPERATION

The invention relates to lighting systems employing high-intensity discharge lamps. More particularly, the invention relates to improved methods for operating high-intensity discharge lamps at multiple output intensities.

5   High-intensity discharge lamps (HID) are increasingly finding use for multi-purpose lighting applications for both large and small indoor and outdoor facilities. Generally, HID lamps include high-pressure sodium (HPS), metal halide (MH) and ceramic MH lamps. Electronic ballasts for the operation of HID lamps often utilize a low-frequency (~100Hz) square wave lamp current. It is known that drive currents containing high-frequency (HF)

10   components may cause acoustic resonances in HID lamps. Therefore, the high-frequency (10 kHz -1 MHz) ripple level in HID ballast units is kept very low to avoid HF power components that may induce acoustic resonances in the lamp. It is also known that the sensitivity to acoustic resonances is related to the operating pressure of the lamp and the power density. Generally, HID lamps are more sensitive to acoustic resonances at higher

15   operating pressures.

The electrode behavior of an HID lamp is strongly related to the drive current level and the operating frequency of the HID lamp. It is generally known that when the HID drive current level is reduced, such as in a dimmed situation that the lamp electrodes do not perform adequately. Dimming an HID lamp using a low frequency square wave may result

20   in flicker, blackening of the arc tube or even extinguishing of the lamp altogether. Therefore, HID lamps are limited in output intensity range based upon the rated power output and the electrode design of the lamp.

Therefore, it would be desirable to provide a method of operating HID lamps that overcomes these and other limitations.

25   In accordance with the present invention, a method for providing bi-state power operation of an HID lamp system is provided. The method provides for determining a power mode control selection, where a high power mode and a low power mode are selectable. The method further provides for determining a modulation to generate a driving signal based on

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the determined power mode control selection, generating a driving signal based on the determined modulation, and applying the generated driving signal to the HID lamp.

The present invention further provides a system to provide bi-state power operation of an HID lamp system. The system includes means for determining a power mode control selection and, means for determining a modulation to generate a driving signal based on the determined power mode control selection.

5   In accordance with another aspect of the invention a computer readable medium having instructions for bi-state power operation of an HID lamp system is provided. Instructions for determining a power mode control selection, and instructions for determining a modulation to generate a driving signal based on the determined power mode are provided.

The foregoing and other features and advantages of the invention are apparent from

10   the following detailed description of exemplary embodiments, read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the invention rather than limiting, the scope of the invention being defined by the appended claims and equivalents thereof.

FIG. 1 is a block diagram of a bi-state HID system.

15   FIG. 2 is a block diagram of a bi-state HID ballast.

FIG. 3 illustrates an embodiment of an HID driver circuit as in FIG. 2 and signal modes in accordance with the present invention.

FIG. 4 is a flow diagram of a process for providing bi-state power operation of an HID lamp system in accordance with the present invention.

20   In the following description the term "coupled" means either a direct connection between the things that are connected, or a connection through one or more active or passive devices that may or may not be shown, as clarity dictates.

FIG. 1 is a block diagram of a bi-state HID system. FIG. 1 illustrates a bi-state HID system **100** comprising a bi-state HID ballast **120** (hereinafter, ballast), and an HID lamp **130**.

25   The bi-state HID ballast is shown coupled to the HID lamp **130**. An embodiment of the ballast **120** will be described in further detail in reference to FIGS. 2 and 3.

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The bi-state HID ballast **120** is generally comprised of several components that work together to provide power mode control, and to supply a power signal to the HID lamp **130** at two selected power levels. The ballast **120** is arranged to determine a power mode control selection, determine a modulation to generate a driving signal based on the determined power mode control selection, generate a driving signal based on the determined modulation, and apply the generated driving signal to the HID lamp **130**. The driving signal is typically representative of one of two configurable operational power levels for the HID lamp **130**. In one embodiment, a low power mode of the bi-state HID system **100** includes driving the HID lamp **130** with a low-power high-frequency square wave for dimmed HID operation.

The HID lamp **130** is a high-intensity discharge lamp such as, for example, a metal halide (MH), a ceramic MH, and a high pressure sodium (HPS) type. The HID lamp may have any full-power wattage rating. In one embodiment, the HID lamp is a 400W ceramic MH capable of operation at full power (400W) or at a reduced power level of approximately 100W using the bi-state HID system **100** and method of the present invention.

FIG. 2 is a block diagram of a bi-state HID ballast as in the ballast **120** of FIG. 1. FIG. 2 illustrates a bi-state HID ballast **120** comprising a mode control system **221**, a power supply **222**, and an HID driver circuit **220**. The mode control system **221** is shown comprising a high-frequency/low-frequency (HF/LF) select control **223**, and a transition point select control **224**. In FIG. 2 the mode control system **221** is shown coupled to the power supply **222**. The power supply **222** is shown coupled to the HID driver circuit **220**. An oscillator circuit is contained in at least one of the various components of the bi-state HID ballast **120** that may be employed to generate high frequency square waves. In one embodiment, the bi-state HID ballast **120** is enabled to produce square wave power signals on the order of 40 Hz to over 1MHz. Many additional components known in the art, may be included in the bi-state HID ballast **120** but are omitted for clarity.

In operation, the mode control system **221** determines a power mode control selection and determines a modulation to generate a driving signal based on the power mode control selection. The HF/LF select control **223** enables selection between high-frequency and low-frequency operation of the ballast **120**. The transition point select control **224** enables selection of a transition point between high and low power modes of operation. It is desirable to allow adjustment of the power mode transition point so that the power levels are optimized for the particular HID lamp **130**.

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In one embodiment, the transition point control **224** allows for a continuously variable setting of the transition between the low-end and the high-end of the HID lamp **130** illumination range. The mode control system **221** may include, for example, a discrete circuit with user inputs, a microcontroller, and a software module. In one embodiment, the mode

5   control system **221** includes a microcontroller having an instruction set able to configure the mode control system **221** for bi-state low-power/high-power operation with a variety of HID lamps of different construction and output ratings. In another embodiment, a user interface may be included for making adjustments to mode control system **221**. In yet another embodiment, the mode control system **221** may be preconfigured at manufacture.

10   The power supply **222** couples power from a raw power source to the HID driver circuit **220**. The power supply **222** may be a regulated or unregulated power source. In one embodiment, the power supply **222** is a switch-mode type allowing reduced size, weight, cost, and heat production. In another embodiment, the power supply **222** is controlled by the mode control system **221**. In this embodiment, the mode control **221** sends a signal

15   containing modulation signal instruction information that the power supply **222** uses to produce a modulated output signal to drive the HID driver circuit **220**.

The HID driver circuit **220** couples power from the power supply **222** to the HID lamp **130**. The HID driver circuit **220** may be any circuit arrangement that is enabled to provide both high and low frequency square wave signals to drive the HID lamp **130**. In the

20   embodiment illustrated in FIG.3, the HID lamp driver **220** is a half-bridge-commutating-forward (HBCF) circuit configuration. Those skilled in the art will recognize that many other circuit configurations may be employed for driver circuit **220**, such as, for example, the FBCF and down-converter topologies.

FIG. 3 illustrates an HID driver circuit and the corresponding signal modes **300**.

25   Lamp driver circuit **220** includes transistors **T1**, and **T2**, diodes **D1**, and **D2**, inductor **L**, and capacitors **C1**, and **C2**. The HID lamp **130** is shown coupled to the driver circuit **220**. Note that in the embodiment of FIG. 3 the capacitors **C1** and **C2** generally will have a very large capacitance.

In operation, driver circuit **220** of FIG. 3 has signals **A** and **B** applied to the bases of transistors **T1** and **T2** respectively. Generally, signals **A** and **B** are periodic signals, comprising pulse trains and square waves depending on the power mode configuration of the ballast **120**. Driver circuit **220** may be operated in two distinctly different modes, low-

5   frequency high-power mode and high-frequency low-power mode, depending upon input signals **A** and **B**.

In HF mode **310**, signals **A** and **B** are square waves of identical frequency having 180 degrees of phase lag. Generally, in HF mode **310**, signals **A** and **B** have frequencies on the order of 20-110 kHz, although for some applications it is beneficial to approach frequencies

10   of 1 MHz or greater. Simultaneous application of signals **A** and **B** to driver circuit **220** produces an output signal across the HID lamp **130** of substantially similar frequency to the HID lamp. Under high power conditions, an HF drive signal would normally engender acoustic resonances in the HID lamp **130**. However, reducing the drive signal power level of the HF drive signal allows operation of the HID **130** at very reduced output power without

15   lamp resonances, lamp flicker, tube blackening and other anomalous side effects of low-power LF square-wave operation.

In LF mode **320**, signals **A** and **B** comprise periodic pulse trains of high power HF square waves. Short pulse trains appear at regular intervals depending on the desired drive frequency, and decline to zero during intervals between the pulse trains. The pulse trains of

20   signal **A** and signal **B** alternate. The pulse trains generally consist of several cycles of a high-frequency square wave followed by a period of zero output equal to several times the period of the high-frequency square wave. Application of the signals to the driver circuit **220** produces a LF output signal across the HID lamp **130**. Generally, in LF mode **320**, the resultant driving signal frequencies are on the order of 40-1000Hz. The driver circuit **220**

25   therefore is capable of bi-state power drive for the HID lamp providing both LF high-power operation, and HF low-power operation without acoustic resonances or flicker and lamp burn.

In the following process description certain steps may be combined, performed simultaneously, or in a different order without departing from the invention.

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FIG. 4 is a flow diagram of a process for providing bi-state power operation of an HID lamp system. Generally, a bi-state HID system **100** includes a ballast **120** and an HID lamp **130**. Process **400** begins in step **410**. In step **410**, a power mode control selection is determined. A power mode control selection may be an automated process or a user

5 selection. A power mode determination may be made at any time, such as, for example, while the HID lamp **130** is operating. In one embodiment, a user selects high-power or low power HID lamp **130** operation. In another embodiment, a transition point from high-power mode to low-power operation is selected. In yet another embodiment, a microcontroller determines a selection of power mode and/or transition point. In a further embodiment, the

10 transition point is configurable within a range of HID lamp **130** operational power output levels.

In step **420**, a modulation is determined to generate a driving signal based on the determined power mode control selection determined in step **410**. The modulation determination is made at any time after the power mode control selection is determined. The

15 modulation determination may be an analog or digital process, or a combination of the two. Generally, the modulation determination involves determining a periodic signal frequency and signal power level necessary to produce either a HF low-power drive signal or a LF high-power drive signal. A mode control system **221** may be employed to determine a modulation.

20 In step **430**, a driving signal is generated based on the determined modulation. The driving signal may be generated at any time after the modulation is determined in step **420**. Generating a driving signal typically involves coupling a modulated power signal to a driver circuit **220**.

In step **440**, the driving signal generated in step **430** is applied to an HID lamp **130**.

25 The driving signal is applied at any time after generation, and generally occurs as a continuous process with the driving signal generation.

While the preferred embodiments of the invention have been shown and described, numerous variations and alternative embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.

CLAIMS:

1.   A method for providing bi-state power operation of a HID lamp system comprising:

determining a power mode control selection;

determining a modulation to generate a driving signal based on the determined power mode control selection;

generating a driving signal based on the determined modulation; and

applying the generated driving signal to the HID lamp.

2.   The method of claim 1 wherein the power mode control is selectable between a high power mode and a reduced power mode.

3.   The method of claim 1 wherein the generated driving signal is a low-frequency square wave responsive to determining a high power mode control selection.

4.   The method of claim 1 wherein the generated driving signal is a high-frequency square wave responsive to determining a low power mode control selection.

5.   The method of claim 1 wherein determining a power mode selection includes determining a power mode transition point for switching between the high power mode and the low power mode.

6.   The method of claim 5 wherein the power mode transition point is selectable.

7.   The method of claim 5 wherein the power mode transition point is variable.

8.   The method of claim 1 the driving signal is generated using an HBCF circuit.

9. The method of claim 8 wherein determining a modulation includes producing a first modulation signal and a second modulation signal for enabling the HCBF circuit to generate the driving signal.

10. The method of claim 9 wherein the first modulation signal and the second modulation signal comprise high-frequency square wave signals having the same frequency but opposite phase and wherein the signals are simultaneously applied to the HBCF to generate a high-frequency drive signal.

11. The method of claim 9 wherein the first modulation signal and the second modulation signal comprise high-frequency square wave signals alternated with zero signal wherein the first and second modulation signals are applied to the HBCF to generate a low frequency drive signal.

12. A computer readable medium having computer executable instructions for providing bi-state power operation of a HID lamp system comprising:
    computer readable code for determining a power mode control selection; and
    computer readable code for determining a modulation to generate a driving signal based on the determined power mode control selection.

13. The computer readable medium of claim 12 wherein the power mode control is selectable between a full output power HID lamp operation and a reduced output power HID lamp operation.

14. The computer readable medium of claim 12 wherein determining a power mode selection includes determining a power mode transition point for switching between the high power mode and the low power mode.

15.   The computer readable medium of claim 14 wherein the power mode transition point is variable.

16.   The computer readable medium of claim 12 wherein the modulation includes a low-frequency periodic signal when the HID lamp is selectably operated at full power and wherein the modulation includes a high-frequency periodic signal when the HID lamp is selectably operated at reduced power.

17.   The computer readable medium of claim 12 wherein the low-frequency periodic signal comprises a square wave.

18.   The computer readable medium of claim 12 wherein the high frequency periodic signal comprises a square wave.

19.   A system to provide bi-state power operation of an HID lamp system comprising:

means for determining a power mode control selection wherein a high power mode and a low power mode are selectable; and

means for determining a modulation to generate a driving signal based on the determined power mode control selection.

ABSTRACT

Bi-state power operation of an HID lamp system. A power mode control selection determined where a high power mode and a low power mode are selectable. A modulation is determined to generate a driving signal based on the determined power mode control selection. A driving signal is generated based on the determined modulation. The generated driving signal is then applied to the HID lamp. A method of operating an HID lamp is also provided. Power is coupled to an HID lamp with a selectable power signal where the power signal is selectable for full power or reduced power operation.
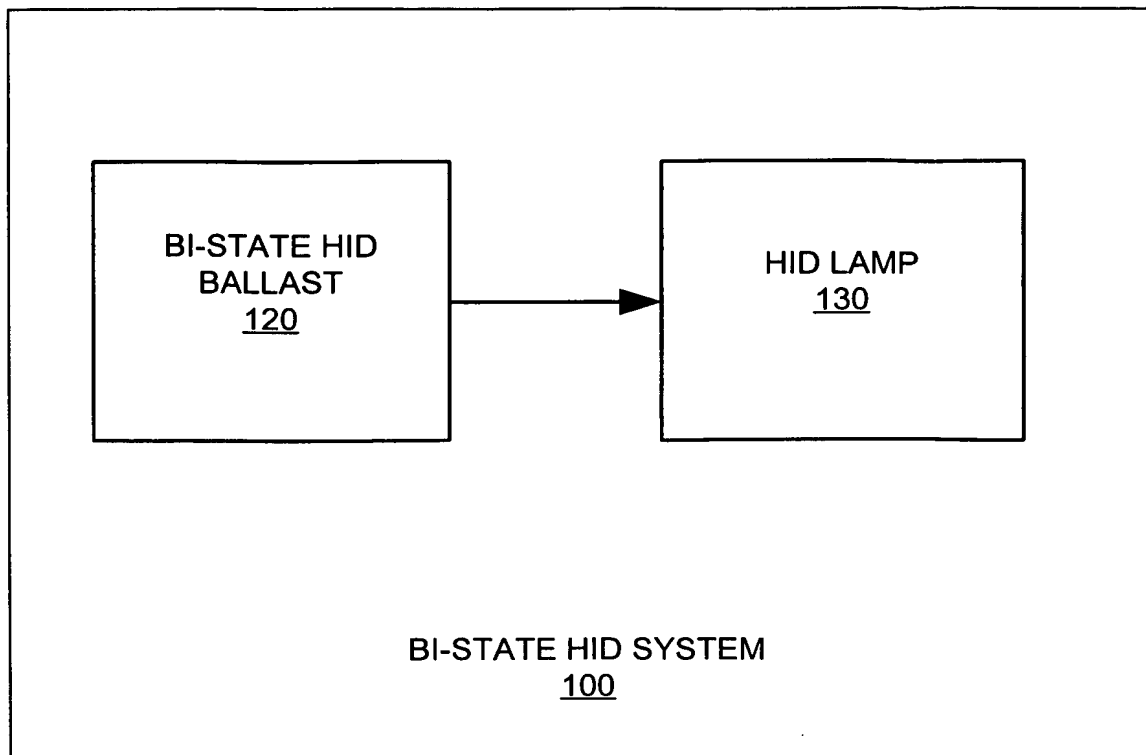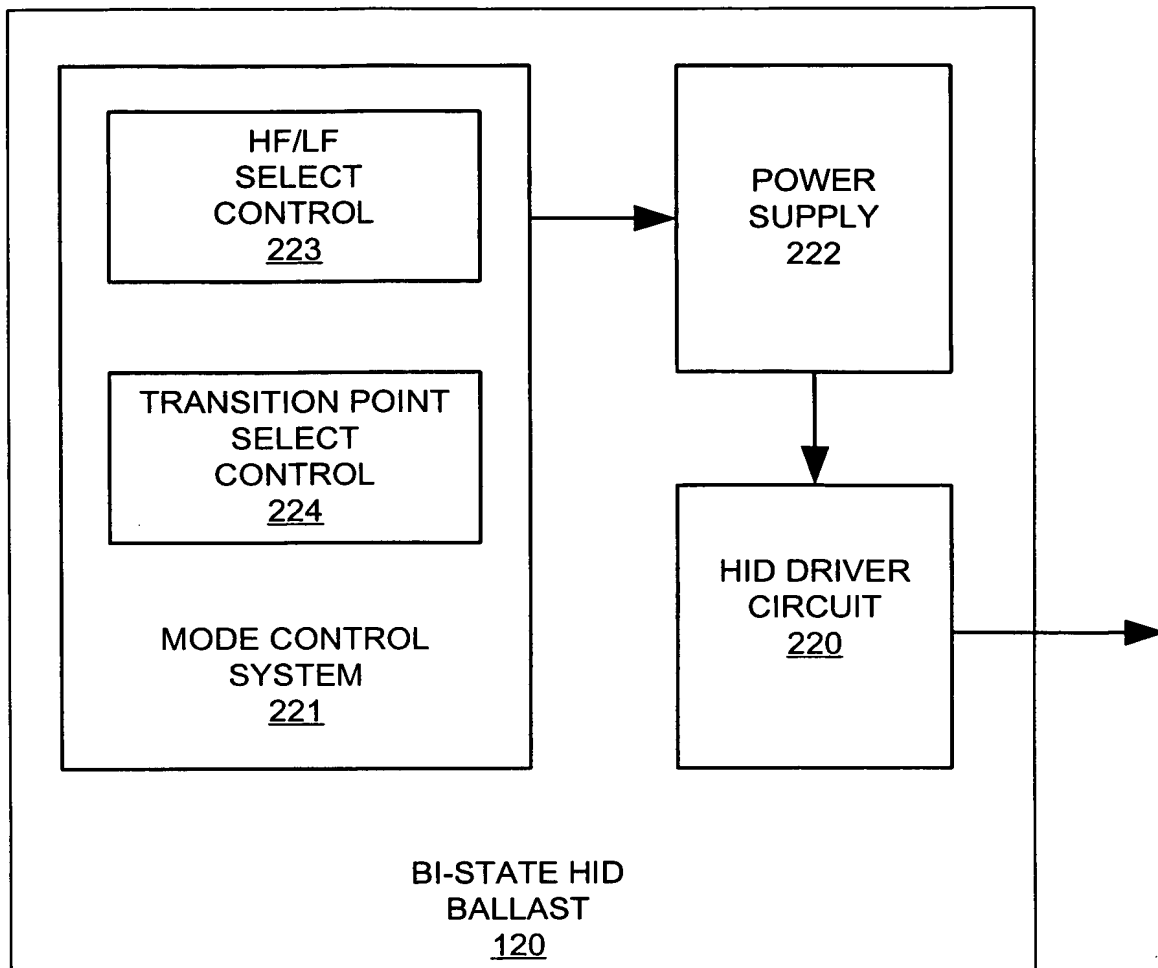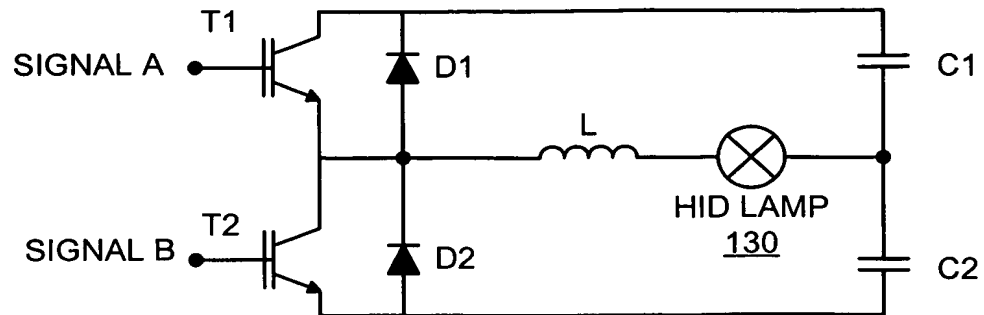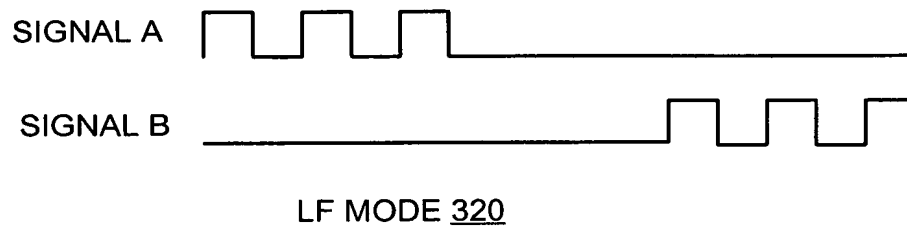
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│                                                                │
│   ┌──────────────────┐              ┌──────────────────┐      │
│   │                  │              │                  │      │
│   │   BI-STATE HID   │              │    HID LAMP      │      │
│   │    BALLAST       │─────────────▶│     130          │      │
│   │     120          │              │                  │      │
│   │                  │              │                  │      │
│   └──────────────────┘              └──────────────────┘      │
│                                                                │
│                                                                │
│                    BI-STATE HID SYSTEM                         │
│                          100                                   │
│                                                                │
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FIG. 1

FIG. 2

LAMP 130 AND DRIVER CIRCUIT 220

HF MODE 310

LF MODE 320
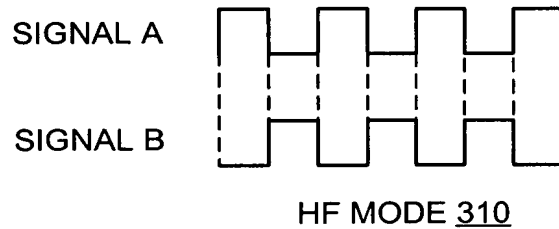
HID DRIVER CIRCUIT AND SIGNAL MODES
300

FIG. 3

400

BEGIN

DETERMINE POWER MODE CONTROL SELECTION — 410

DETERMINE MODULATION TO GENERATE A DRIVING SIGNAL
BASED ON THE DETERMINED POWER MODE CONTROL
SELECTION — 420

GENERATE A DRIVING SIGNAL BASED ON THE DETERMINED
MODULATION — 430

APPLY GENERATED DRIVING SIGNAL TO HID LAMP — 440

END

FIG. 4